CLAIMS

What is claimed is:

1. A self-controlling fuel cell power system, comprising:

a fuel cell subsystem having one or more fuel cells and a plurality of operating states;

one or more sensors configured to sense one or more parameters of the fuel cell subsystem; and

a controller configured to transition the fuel cell subsystem among the operating states responsive to the one or more sensed parameters.

2. The system of claim 1 wherein the operating states include a Discharge state wherein the one or more fuel cells expend fuel to deliver power.

3. The system of claim 2 wherein the operating states include a Regenerate state wherein the fuel cell subsystem converts expended fuel into reusable fuel.

4. The system of claim 3 wherein the operating states include a Flush state wherein the one or more fuel cells are reconditioned.

5. The system of claim 4 wherein the fuel cell parameters include a fuel level, a cell voltage developed by one or more of the fuel cells, and a power demand from a load.

6. The system of claim 5 wherein the operating states include an Idle state, and wherein the controller maintains the fuel cell subsystem in Idle responsive to sensing the fuel level within a desired level range, sensing no maintenance demand, and sensing no power demand from the load.

7. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Idle and Regenerate states responsive to sensing the fuel level below the desired level range while operating in the Idle state.

8. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Idle and Discharge states responsive to sensing the power demand while operating in the Idle state.

9. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Idle and Flush states responsive to a maintenance demand while operating in the Idle state.

10. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Regenerate and Idle states responsive to sensing the power demand while operating in the Regenerate state.

11. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Regenerate and Idle states responsive to sensing the fuel level within the desired level range while operating in the Regenerate state.

12. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Discharge and Flush states responsive to sensing no power demand while operating in the Discharge state.

13. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Discharge and Flush states responsive to sensing the fuel level below the desired level range while operating in the Discharge state.

14. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Flush and Idle states responsive to sensing the power demand while operating in the Flush state.

15. The system of claim 6 wherein the controller transitions the fuel cell subsystem between the Flush and Idle states responsive to sensing no maintenance demand while operating in the Flush state.

16. The system of claim 1 wherein the fuel cell subsystem has a non-operating Shutdown state, and wherein the controller may transition the fuel cell subsystem from at least one of the operating states to the Shutdown state responsive to sensing one or more of the parameters outside of a desired range.

17. The system of claim 16 wherein the controller may transition the fuel cell system from at least one of the operating states to the Shutdown state responsive to a manual control signal.

18. The system of claim 16 wherein one of the sensed parameters is a fuel cell temperature.

19. The system of claim 16 wherein one of the sensed parameters is the cell voltage.

20. The system of claim 16 wherein the fuel cell subsystem further comprises one or more reactants contained in the fuel cells, and wherein the fuel cells are deprived of at least one of the reactants during the Shutdown state.

21. A self-controlling fuel cell power system, comprising:

a fuel cell subsystem comprising:

a plurality of operating states;

one or more fuel cells for developing power; and

a heating means for heating the one or more fuel cells;

one or more sensors configured to sense one or more parameters of the fuel cell subsystem; and

a controller configured to transition the fuel cell subsystem to a selected one of the operating states responsive to the one or more sensed parameters, wherein the operating states include a Discharge state wherein the heating means may be energized by the power developed by the fuel cells.

22. The system of claim 21 wherein the heating means comprises an electrical resistance heater.

23. The system of claim 22 wherein the one or more fuel cells develop power by expending fuel, and wherein the heater delivers heat to the fuel.

24. The system of claim 23 wherein the one or more fuel cells develop power by chemical reaction of the fuel and oxygen, and wherein the heater delivers heat to the oxygen.

25. The system of claim 22 wherein the heater delivers heat to one or more electrodes of the one or more fuel cells.

26. The system of claim 25 wherein the one or more electrodes comprise cathodes.

27. A method of operating a self-controlling fuel cell power system, comprising:

sensing one or more parameters of a fuel cell subsystem; and

transitioning the fuel cell subsystem among a plurality of operating states responsive to the one or more sensed parameters.

28. The method of claim 27 wherein the sensing step further comprises sensing a maintenance demand, and wherein the transitioning step further comprises transitioning the fuel cell subsystem into a Flush state responsive to sensing the maintenance demand.

29. The method of claim 28 wherein the sensing step further comprises sensing a power demand, and wherein the transitioning step further comprises transitioning the fuel cell subsystem into a Discharge state responsive to sensing the power demand.

30. The method of claim 29 wherein the sensing step further comprises sensing a fuel level, and wherein the transitioning step further comprises transitioning the fuel cell subsystem into a Regenerate state responsive to sensing the fuel level below a desired range.

31. The method of claim 30 wherein the operating states include an Idle state, and wherein the transitioning step further comprises transitioning the fuel cell subsystem into an Idle state responsive to sensing no maintenance demand, sensing no power demand, and sensing the fuel level within a desired level range.

32. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Idle and Regenerate states responsive to sensing the fuel level below the desired level range while operating in the Idle state.

33. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Idle and Discharge states responsive to sensing the power demand while operating in the Idle state.

34. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Idle and Flush states responsive to sensing the maintenance demand while operating in the Idle state.

35. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Regenerate and Idle states responsive to sensing the power demand while operating in the Regenerate state.

36. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Regenerate and Idle states responsive to sensing the fuel level within the desired level range while operating in the Regenerate state.

37. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Discharge and Flush states responsive to sensing no power demand while operating in the Discharge state.

38. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Discharge and Flush states responsive to sensing the fuel level below the desired level range while operating in the Discharge state.

39. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Flush and Idle states responsive to sensing the power demand while operating in the Flush state.

40. The method of claim 31 further comprising transitioning the fuel cell subsystem between the Flush and Idle states responsive to sensing no maintenance demand while operating in the Flush state.

41. The method of claim 31 further comprising transitioning the fuel cell subsystem to a non-operating Shutdown state responsive to sensing one or more of the parameters outside of a desired range.

42. The method of claim 41 wherein the one or more parameters is a temperature in the fuel cell subsystem.

43. The method of claim 41 wherein the one or more parameters is a voltage in the fuel cell subsystem.

44. The method of claim 41 wherein the one or more parameters is an electrical current in the fuel cell subsystem.

45. The method of claim 41 wherein the one or more parameters is a pressure in the fuel cell subsystem.

46. The method of claim 41 wherein the one or more parameters is a fluid flow in the fuel cell subsystem.

47. The method of claim 41 further comprising transitioning the fuel cell system from at least one of the operating states to the Shutdown state responsive to a manual control signal.

48. The method of claim 41 further comprising transitioning the fuel cell subsystem into the Shutdown state by depriving fuel cells of one or more reactants.

49. A method of operating a self-controlling fuel cell power system to transition a fuel cell subsystem among a plurality of operating states, the subsystem having one or more fuel cells, the method comprising:

sensing for a maintenance demand;

sensing for a fuel level;

sensing for a power demand;

operating the fuel cell subsystem in an Idle operating state responsive to sensing no maintenance demand, sensing a fuel level within a desired level range, and sensing no power demand;

transitioning the fuel cell subsystem from the Idle state to a Flush operating state, and operating the subsystem in a Flush state, responsive to sensing the maintenance demand while operating in the Idle state;

transitioning the operating state from the Idle state to a Discharge operating state, and operating the subsystem in the Discharge state, responsive to sensing the power demand while operating in the Idle state;

transitioning the operating state from the Idle state to a Regenerate operating state, and operating the subsystem in the Regenerate state, responsive to sensing the fuel level outside a desired level range while operating in the Idle state.

50. The method of claim 49 further comprising transitioning between the Idle and Flush states responsive to sensing a cell voltage outside a desired range while operating in the Discharge state.

51. The method of claim 49 further comprising transitioning between the Regenerate and Idle states responsive to sensing a power demand while operating in the Regenerate state.

52. The method of claim 49 further comprising transitioning between the Discharge and Flush states responsive to sensing the fuel level outside a desired level range while operating in the Discharge state.

53. The method of claim 49 further comprising transitioning between the Flush and Idle states responsive to sensing no maintenance demand while operating in the Flush state.

54. The method of claim 49 wherein operating the fuel cell subsystem in the Flush state further comprises:

sensing an electrolyte concentration; and

if the concentration is below a desired level, circulating the electrolyte through the one or more fuel cells;

if the concentration is above the desired level, transitioning the fuel cell subsystem to the Regenerate state.

55. The method of claim 49 wherein operating the fuel cell subsystem in the Regenerate state further comprises:

transporting electrolyte solution to an electrolyzer responsive to sensing a fuel level below a desired range;

recovering fuel from the electrolyte solution by means of the electrolyzer; and

transporting the recovered fuel to the one or more fuel cells.

56. The method of claim 55 further comprising maintaining the electrolyte within a desired temperature range while operating the system in the Regenerate state.

57. The method of claim 56 wherein the temperature range is between about 25 degrees and about 55 degrees C.

58. The method of claim 49 wherein operating the fuel cell subsystem in the Discharge state further comprises:

delivering oxygen to the one or more fuel cells;

circulating fuel through the one or more fuel cells;

developing a voltage across the one or more fuel cells by reaction of oxygen and fuel;

sensing the developed voltage; and

delivering power from the one or more fuel cells to meet the demand when the sensed voltage achieves a value within a desired range.

59. The method of claim 58 further comprising maintaining the one or more fuel cells within a desired temperature range while operating the system in the Discharge state.

60. The method of claim 59 wherein the temperature range is between about 25 degrees and about 55 degrees C.

61. The method of claim 49 wherein operating the system in the Discharge state further comprises:

delivering an air stream containing oxygen to the one or more fuel cells;

circulating fuel through the one or more fuel cells;

generating power from the one or more fuel cells by reaction of oxygen and fuel; and

heating the one or more fuel cells by means of a heat derived from the power, thereby facilitating the reaction.

62. The method of claim 61 wherein the heating means comprises an electrical resistance heater.

63. The method of claim 62 wherein the heater delivers heat to the circulating fuel.

64. The method of claim 62 wherein the heater delivers heat to the air stream.

65. The method of claim 62 wherein the heater delivers heat to one or more fuel cell electrodes.

66. The method of claim 65 wherein the one or more electrodes comprise one or more cathodes.

67. The method of claim 58 wherein operating the system in the Discharge state further comprises:

sensing temperature of the one or more fuel cells; and

depriving the one or more fuel cells of one or more reactants responsive to sensing a temperature above a desired range.

68. The method of claim 67 wherein the depriving step comprises depriving the one or more fuel cells of oxygen.

69. The method of claim 67 wherein the depriving step comprises depriving the one or more fuel cells of fuel.

70. The method of claim 58 wherein operating the system in the Discharge state further comprises:

sensing voltage developed by one or more fuel cells; and

depriving the one or more fuel cells of one or more reactants responsive to sensing a voltage below a desired range.

71. The method of claim 70 wherein the depriving step comprises stopping the delivery of oxygen.

72. The method of claim 70 wherein the depriving step comprises stopping the circulation of fuel.